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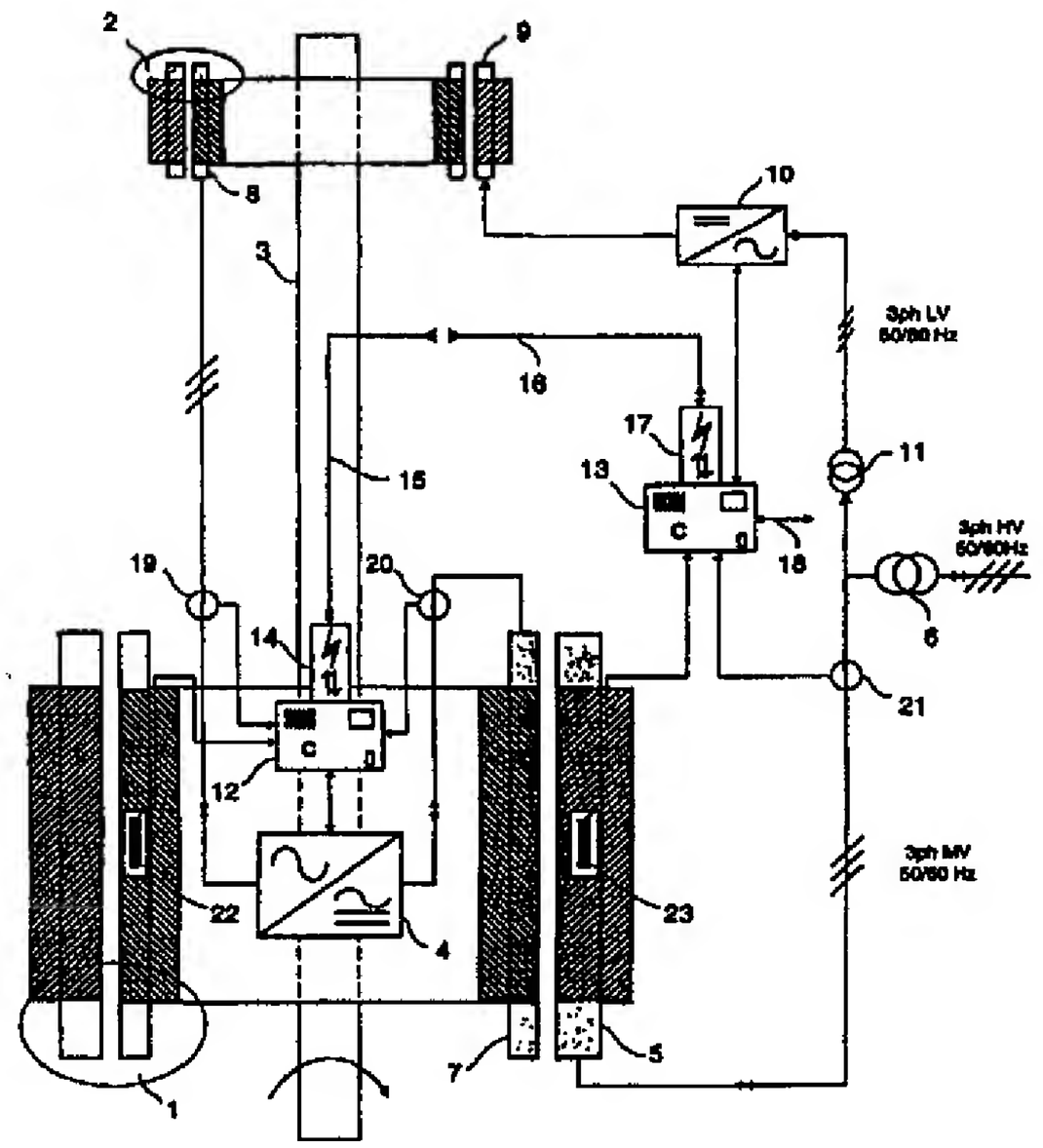
(57) Abstract

The invention relates to a power converter which comprises an electric machine (1, 2) with a digital processor (12), rotating with the shaft of the machine, which digital processor together with a stationary digital processor (13), via a wireless digital communication link (14, 15, 16, 17), digitally control a converter (4) rotating with the shaft.



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Power converter with rotating/stationary communication/ processing means.

TECHNICAL FIELD

The present invention relates to a method for power conversion between mechanical and electric power and conversion between electric and mechanical power, and to devices for carrying out the method. The power conversion is performed with the aid of a power converter which comprises at least one rotating electric machine with a mechanical shaft and

- at least one digital processor which rotates with the shaft and which together with at least one stationary digital processor performs control, etc.

- at least one static converter rotating with the shaft, and

- at least one digital wireless communication link between rotating and stationary parts.

The power converter is intended to be connected to an external power network or may operate as a sole electric generator for supplying a power network. When connected to an external power network, the power converter may generate a frequency which is synchronous with the existing power network also at a varying speed of rotation of the electric machine. When the power converter is the sole power feeder to a power network, that is, so-called separate operation, it may generate a constant "synchronous" mains frequency also at a varying speed of rotation.

BACKGROUND ART

Generally, the following applies to alternating-current machines, referred to below as ac machines, namely

- that they may be designed for constant or variable speed, and

- that they are able to operate in generator and/or motor mode.

There is a "background art" which is specific to the two embodiments. Ac machines, which are substantially designed for generator operation, may, however, for example during start-up, operate as a motor. Also, ac machines, which are substantially designed for motor operation, may briefly, for example during a stopping/braking process, operate as a generator. It is also known that ac machines may be designed for both generator and motor operation, for example for generator operation during the day and for motor operation for a pumping plant during the night.

Ac machines which are intended to rotate at a constant speed are designed as so-called synchronous machines, in which case the magnetization of the rotor is performed with direct current. This means that the magnetic flux in the machine is stationary relative to the rotor. This causes the rotor to rotate at a so-called synchronous speed, which is determined by the number of poles of the stator winding and the frequency of the current of the stator winding. The relationship between the speed of rotation of the rotor of an ac machine, the number of poles of the machine, and the frequency of the voltage is described in detail in Swedish patent application SE 9901553-9, "A constant-frequency machine ...". That application also describes how to proceed for achieving a constant (mains) frequency at a varying speed of an electric machine.

The synchronous machine is the totally dominating ac machine which is used both in hydroelectric and thermal

plants. There are a number of reasons why this is the case, among other things, the high efficiency of the synchronous machine, its ability to operate in separate operation, that is, in power networks without other synchronous machines, as well as its robust and cost-effective rotor design.

The principal voltage supply needed by ac machines in motor operation and the auxiliary power supply needed by ac machines in generator operation nowadays, to an increasing extent, take place by means of converters. For control of ac machines with associated converters, digital computers are substantially used nowadays. Converters have so far normally been located stationary and have been connected between the ac machine and the power network in question, that is, the converter has substantially been stationary. The same applies also to the computers which take care of the control and the feedback control.

Converters rotating with the shaft, and being in the form of ac-to-dc converters, have existed on the market for some time in the form of brushless exciters for the field winding of the rotor of an ac machine. One example of such an exciter is disclosed in the ABB pamphlet "Brushless exciter" SEGEN/HM 8-001. The pamphlet shows that the converter, rotating with the shaft, is substantially/mostly designed with diodes and that the field current is controlled by means of an exciter, rotating with the shaft, via the stator current of the exciter. One disadvantage of a brushless exciter, according to the described one with a converter based on diodes, is the slow dynamics of the magnetization system. When using a so-called "Power System Stabilizer", it is assumed that the magnetization system has a sufficiently short reaction time. This is obtained if the ac-to-dc converter is designed as a thyristor converter. Such a converter is

used in equipment disclosed in US 3,671,850, "Electric generator control system with radio feedback loop". For control of the firing pulses of the rotating thyristor converter, radio communication is used and the control system is otherwise based on analogue technique. Here, there are no dynamics or measurement of parameters which are included in the control, as, for example, the temperature-dependent resistance of the rotor winding, etc.

Swedish patent application SE 9901553-9 "A constant-frequency machine ..." describes an electric machine composed of an ac machine, which in its basic design comprises a main machine and a regulating machine with a common mechanical shaft on which a converter is arranged to rotate with the shaft. The main machine is designed with ac windings in both the stator and the rotor. The main task of the regulating machine is to provide the rotor winding of the main machine with control power/control frequency for the control range of interest as regards the speed of rotation, the frequency and the voltage of the electric machine. The regulating machine may also be utilized for a plurality of side functions, such as, for example, as starting motor for the main machine and for carrying away the starting losses of the main machine to an external resistor. The converter rotating with the shaft has also several functions, which are described in greater detail in the above-mentioned Swedish patent application. To sum up, its main task is to function as an ac-to-ac converter during operation. During a starting cycle, it shall be able to function as an ac polyphase coupler or as an ac phase-angle controller/voltage controller or as an ac short-circuit coupler for the rotor winding of the regulating machine. During controlled braking and/or stopping, the converter shall be able to function as an ac phase-angle controller/voltage controller or as an ac polyphase coupler. The

communication of data to and from the rotor is, however, not described.

A special embodiment of rotating electric machines is described in WO 97/45919. The high-voltage stator winding is based on cable technology. This means that no transformer for connection to a high-voltage network is needed. Machines designed with this type of stator winding are characterized in that they have very low current density in the stator conductors and in that the cooling is performed essentially at ground potential in the laminated core of the stator. By a suitable design of the area and/or protection device of the windings of the rotor, the machine has a good ability to generate temporarily, for tens of minutes and sometimes up to several hours, very large reactive power and rotor current. One embodiment of a protection device in this connection is described in WO 98/34312. In this protection device, the temperature of the rotor is reproduced in a protective relay located in the plant. The communication of data to and from the rotor is, however, not described.

A special embodiment of dc magnetization of an electric rotating machine, rotating at constant speed, is described in a patent application, PCT/EP98/007744, for "Power Flow Control" in a transmission line. The stator windings of the electric machine are here connected in series with the conductors of the transmission line without an interconnected neutral point. The rotor of the electric machine is provided with two/three dc rotor windings, displaced 90/120 electrical degrees, for control of amplitude and phase of the voltage of the electric machine. Supply of the rotor winding is performed via a magnetizing exciter, rotating with the shaft, and a converter/ac-to-dc converter for each one of the rotor windings. The same patent application further describes a more developed "Power Flow Control" with a

second electric machine, connected to the same shaft as the first electric machine, shunt-connected to the transmission line, the second electric machine having a converter/ac-to-dc converter rotating with the shaft. The communication of data to and from the rotor is, however, not described.

During the last few decades, there has been an obvious tendency to miniaturize electronics for signal processing. Telecommunication may be said to be almost completely digital today in all essential parts. The signal processing of the converter technology in control circuits has become miniaturized in the same way such that there are chips with internal digital signal processing especially developed for converters, both as ac-to-dc converters and as ac-to-ac converters. Designing such circuits with analog technique does not entail any added value since the digital resolution both as regards amplitude and time is sufficiently high, while at the same time the possibilities of setting and trimming the parameters of the control circuits at a distance, for example via a digital communication link, are much better.

Electric machine drives with converters rotating with the shaft entail one problem, namely in the form of a considerable need to be able to carry out a number of more or less complicated operations, such as calculations, decisions, storage of data, control, etc. According to the invention, these problems are overcome by means of a computer, rotating with the shaft, where all signal processing takes place in digital form. In addition, there is one problem in the form of a great need to communicate, with high precision and safety, between the computer, which rotates with the shaft, and a stationary computer for transmission of data in both directions. According to the invention, this communication takes

place by utilizing a new technology, so-called telemetry, which has so far been used for wireless communication between substantially stationary units.

Transmission of data of various kinds has long been carried out by means of communication over a wire. Telemetry is the field of science and the technology of wireless automatic transmission of data between two terminals. The telemetry technology came into use as early as 20-30 years ago. In a summary article by J. E. Blalock et al in **Instruments and Control Systems**, Vol. 51, No. 6, June 1978, pp. 45-48, "Telemetry - an easy way to check out rotating machinery", the technology of that time was summarized. In an essay by S. T. Chow and C. H. Chew in Conference Proc. TENCON 84, an Int. Conf. on Consumer & Industrial Electronics & Applications, IEEE, New York, NY, USA, 1984, pp. 3 - 5, "Radio telemetry system for vibration measurement of rotating machinery", it is described how the resonant frequency of turbine blades varies with the speed of rotation. The signals from strain gauges on the rotor blades in the turbine were amplified, modulated and sent from rotating parts to stationary measurement and analysis instruments by frequency modulation, that is, so-called FM.

As regards electric machines, contactless measurement systems were used for transmitting temperature signals from movable parts in transformers in the supply of German railways as early as 25 years ago according to an article "A contactless measurement system for continuous recording of temperatures on rotating parts, especially in electrical machines" in Sci. Translation Service, Santa Barbara , CA, USA, Aug. 1974, 22 pp., by W. Raasch and D. Schein.

In an article "The measurement of strain on a laminated disc flywheel" by A. Owens and P. Williams, published in

International Power Generation, Vol. 6, No. 6, July-Aug. 1983, pp. 24 - 27, it is described how computers are used in connection with the transfer of information from rotating strain gauges on flywheels.

To make possible wireless connections with a range of up to 100 metres between personal computers and pocket computers and between mobile telephones and associated peripheral units, wireless communication for that purpose has been developed at a high rate during the last few decades. There are at present licence-exempt frequency bands, for example 433 MHz and 2.45 GHz, examples of so-called Industrial-Scientific-Medical (ISM) bands, which are utilized for short-distance communication and which function in electromagnetically disturbed environments. IEEE is currently working for standardized communication also on 5 GHz (IEEE 802.11).

The article "Bluetooth-the universal radio interface for ad hoc, wireless connectivity" in Ericsson-Review, Vol. 75, No. 3, 1998, pp. 110-117, is written by J. Haartsen and describes commercially recently available technique for digital communication. Typical data are 1 Mbit/s and the possibility of building up a so-called piconet, that is, communication with a short (< 100 m) range between different stationary units as well as connection to wire-based Local Area Networks (LAN). The connections are so-called Asynchronous Connection Links (ACL), which permit symmetrical and/or asymmetrical transmission of data between a master unit and up to seven slave units. Data may be transmitted at somewhat different speeds depending on the choice and the method of packing and protecting data messages.

Since the emissions of disturbances from converters are low in the GHz range and communication links according to the de-facto standard Bluetooth or the organizational

standard IEEE 802 are strongly immune to electromagnetic interference, wireless communication with up to 721 kbit/s can be ensured between rotating and stationary parts in the power converter in question.

There are a few examples of embodiments and descriptions of problems as to how to digitally carry out measurements on rotating parts and where computers are included for both analysis and communication of information data. One example of this in connection with measurements of both mechanical and electrical quantities of rotors in hydro-electric generators is described in an article "Unique sensor applications for hydroelectric generator rotor-mounted sensor scanning technology" by J. D. Edmonds and T. L. Churchill in IEEE Technical Applications Conference, Northcon/96, Conference Record (Cat. No. 96CH35928), IEEE, New York, NY, USA; pp. 73-77. The article shows that the rotor-mounted scanner of the hydroelectric generator uses a set of sensors for measuring the critical working parameters of the stator. Radiating thermal energy, the air gap between the stator and the rotor, radio frequency radiation and magnetic flux are measured. The combined information from the entire generator permits a continuous evaluation of the state of the generator as well as long-term analysis for maintenance planning. Further, it is stated that to be able successfully to measure parameters of a body rotating at a high speed, for transmission of information data to a central computer for presentation of valuable information to the user, coordination of a plurality of system parts is required, such as a device for mounting the sensors, supply of electronics arranged on the rotor, telemetry for two-way communication, a computer control unit as well as software for control, data conversion, analysis VDU and user VDU. In addition, the maintenance systems must function satisfactorily in a harsh environment which includes high centrifugal forces, great

temperature variations, mechanical vibration, oppositely directed electric and magnetic fields as well as relatively high speeds between the sensors and the objects to be measured.

SUMMARY OF THE INVENTION, ADVANTAGES

As stated in the introductory part of the description, the invention relates to a power converter in the form of an electric machine with a mechanical shaft and at least one digital processor which rotates with the shaft and which, together with at least one stationary digital processor, digitally controls at least one converter rotating with the shaft, at least one digital communication link being provided between rotating and stationary parts.

The digital processor comprises a computer which, in addition to internal control and memory functions, is provided with process-adapted software for the relevant mode of operation/working.

The digital communication link comprises a receiver/transmitter, rotating with the shaft, for receiving/transmitting digital data, connected to the processor rotating with the shaft, an aerial which rotates with the shaft, and a stationary aerial for the wireless digital transmission, as well as a stationary receiver/transmitter, connected to the stationary processor, for receiving/transmitting the above-mentioned digital data.

With the aid of a power converter according to the invention, quantities associated with the power converter, such as torque, speed, active power, reactive power, etc., may be controlled in a brushless manner. It is also possible, in relation to the prior art, to

increase the stability of the electric power systems to which the power converter is connected. Further advantages of the invention are the possibilities of achieving controlled starting, operation, stopping and braking of the electric machine as well as trimming in connection with putting the machine into operation.

Otherwise, the power converter according to the invention comprises the following features:

- the wireless data transmission occurs, in a preferred embodiment, with radio-frequency, digital signals

- the relevance of communicating data is ensured by combinations of models, estimations, expert systems, compression, filtering and error correction

- the need of bandwidth during the communication may be reduced by communicating only the changes in certain of the data-transmitted signals.

The power conversion has an integral control system which comprises the above-mentioned rotating and stationary digital processors with brushless digital communication as well as sensors for measuring and monitoring the relevant quantities. The processors normally operate in a master/slave relationship, with the rotating processor as a slave. The stationary processor substantially controls the power conversion, measures and monitors quantities associated with the stator of the electric machine, and communicates with other external control systems. The main task of the rotating processor is to control the converter which rotates with the shaft of the electric machine, and to measure and monitor quantities associated with the rotor of the machine.

The rotating processor is programmed such that, in case of repeated and difficult disturbances in the wireless digital communication, it may, for a certain period of time, autonomously control, etc., the power converter.

Commissioning of plants with electric machines which include converters traditionally takes place by trimming/adjusting parameters in control systems, etc., when putting the plant into service. The invention permits considerable advantages in this context since this can be made via communication of information data with the aid of wireless transmission to rotating parts. An updating and adjustment of the set parameters may also take place continuously as increased knowledge is gained of the components included and with changes in connected electric power systems during the life of the plant.

As will have been clear from the above, it is thus very important, in connection with electric machines associated with this invention, to be able to start up, trim and then control and protect converters rotating with the shaft. More specifically, it is necessary to fix the times when the conductors which are included in the converters are to start/stop carrying current substantially in order to convert mechanical power into active electric power and/or for generation of reactive electric power, and inversely.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the invention is shown in the accompanying figure. The power converter according to the invention may be used as an electric generator or as an electric motor. In a preferred embodiment, the power converter comprises a rotating electric machine in the form of a main machine 1 and a regulating machine 2 with a common mechanical shaft 3. In the figure, the electric machine

is shown as a vertical-shaft electric machine but it may, of course, be designed as a horizontal-shaft electric machine. On the common shaft, and rotating with the shaft, a converter 4 is arranged in the form of

- an ac-to-ac converter which may be designed as a matrix converter, a cycloconverter or an ac converter with an intermediate dc link for ac supply of the rotor windings (SE 9901553-9), or it may also be designed as
- an ac-to-dc converter for dc supply of the rotor winding(s), for example with an arbitrary phase position relative to the rotor (PCT/EP 98/007744).

The main machine is designed with a stator winding 5 suitably dimensioned for so-called medium voltage, that is, up to 30 kV. For connection to a high-voltage network, a transformer 6 is added. If the machine is designed in accordance with the machine described in WO 97/4519, the stator winding 5 may be dimensioned for high voltage, in which case the transformer 6 is omitted. The rotor winding 7 of the main machine, in the embodiment shown, is designed as an ac winding which, from the ac-to-ac converter, is supplied with the difference frequency (see Swedish patent application SE 9901553-9) which is necessary to obtain the desired frequency of the machine when it operates as a generator and to obtain the desired speed of rotation of the rotor of the electric machine when it operates as a motor.

The rotor winding 8 of the machine supplies the ac-to-ac converter which rotates with the shaft. In the figure, the supply is indicated to take place with a 3-phase voltage. The scope of the invention comprises carrying out the supply in a plurality of different ways, such as, for example, with a 2x3-phase voltage, a 2-phase voltage, a 2x2-phase voltage, or generally with an N-voltage. The stator winding 9 of the regulating machine, in the shown

embodiment, is intended to be supplied with direct current from a controllable converter 10 with separate supply, for example via an auxiliary transformer 11 connected to the electric power network. The stator winding may also alternatively be designed as an ac winding for use in connection with starting of the electric machine.

The converter 4 rotating with the shaft is utilized in combination with the regulating machine and external devices, connected to the regulating machine, for starting, stopping and braking according to SE 9901553-9.

As will be clear from the summary of the invention and the claims, the power converter comprises a digital processor 12, rotating with the shaft of the electric machine, and a stationary digital processor 13. These two processors communicate with each other via one, or two or more, redundant wireless digital communication links. A communication link comprises a receiver/transmitter 14, rotating with the shaft, for receiving/transmitting digital data, connected to the processor 12 rotating with the shaft, an aerial 15 rotating with the shaft, and a stationary aerial 16 for the wireless digital transmission, as well as a stationary receiver/transmitter 17 for receiving/transmitting the above-mentioned digital data, connected to the stationary processor 13. The stationary processor suitably communicates with other stationary units for common control, protection, etc., indicated by the two-way arrow 18.

The task of the processors has been described in broad outline under the summary of the invention. The detailed design of all of these functions such as control, protection, etc., is outside the scope of this invention. However, the accompanying figure indicates a number of measuring devices, for example for current measurement

19, 20 and 21 of the input/output current of the ac-to-ac converter and the current/voltage of the main machine, respectively, as well as temperature measurement 22 and 23 of the rotor/stator winding of the main machine.

The directions of the power flows are also indicated in the figure by means of arrows on current-carrying conductors. Thus, for example, the conductor between the stator winding 5 and the transformer 6 of the main machine is provided with two-way arrows indicating that the electric machine is able to operate both as an electric power generator and as a motor. In the same way, also the signal-carrying conductor/aerial is provided with arrows indicating the direction of transmission of the respective signals.

CLAIMS

1. A power converter comprising at least one rotating electric machine (1, 2), connected to a power network, with a shaft (3),
at least one converter (4) rotating with the shaft,
at least one digital processor (12) connected to one end of a wireless digital communication link (14, 15, 16, 17),
at least one digital processor (13) connected to the other end of the wireless communication link,
characterized in that the digital processor (12), which is connected to one end of the communication link, is arranged as a processor rotating with the shaft, and that the digital processor (13), connected to the other end of the communication link, is arranged as a stationary processor.

2. A power converter according to claim 1, **characterized** in that the wireless digital communication link (14, 15, 16, 17) is arranged with redundancy.

3. A power converter according to claim 1, **characterized** in that the wireless digital communication link (14, 15, 16, 17) is arranged for transmission of signal data in the form of radio-frequency digital signals in both directions between the rotating and the stationary processors.

4. A power converter according to claims 1 and 3, **characterized** in that the wireless digital communication link comprises a receiver/transmitter (14), rotating with the shaft, for receiving/transmitting digital data, an aerial (15) rotating with the shaft, a stationary aerial (16), and a stationary receiver/transmitter (17) for receiving/transmitting said digital data.

5. A power converter according to claim 1, **characterized** in that the rotating processor (12) is programmed to be

able to autonomously control, etc., the power converter for a certain period of time in case of repeated and severe disturbances in the wireless digital communication.

6. A power converter according to claim 1, **characterized** in that the stationary processor (13) is adapted for communication (18) by means of digital wireless or line-bound communication with other stationary processors/units for common control.

7. A power converter according to claim 1, **characterized** in that the rotating electric machine comprises at least one first (1) and one second (2) electric machine with the common shaft, and that the first electric machine functions as a main machine with windings (5, 7) arranged in the stator and rotor of the main machine, and that the second electric machine functions as a regulating machine with windings (8, 9) arranged in the stator and rotor of the regulating machine.

8. A power converter according to claim 1, **characterized** in that the rotating electric machine is arranged with measuring devices (19, 20, 21, 22, 23) for the control parameters of interest.

9. A power converter according to claim 1, **characterized** in that the converter (4) rotating with the shaft (3) is connected between the rotor windings of the main machine (7) and the regulating machine (8), and that, during operation, it is arranged as an ac-to-ac converter and that the converter, during start-up, is arranged as an ac polyphase coupler or as an ac phase-angle controller/voltage controller or as an ac short-circuit coupler, and that, during controlled braking and stopping, it is arranged as an ac polyphase coupler or as an ac phase-angle controller/voltage controller, or as an ac short-circuit coupler.

10. A power converter according to claim 1, **characterized** in that both the digital processor (12), rotating with the shaft, and the stationary digital processor (13) comprise a computer with all the units associated with the operative system of a computer, such as input/output units, memories, etc., and being provided with process-adapted software for the different modes of operation/working of the power converter.

11. A power converter according to claim 1, **characterized** in that the wireless digital communication link comprises at least one receiver/transmitter (14), rotating with the shaft, for receiving/transmitting digital data and which is connected to the processor rotating with the shaft, an aerial (15) rotating with the shaft and a stationary aerial (16) for the wireless digital transmission, as well as a stationary receiver/transmitter (17), for receiving/transmitting said digital data, and which is connected to the stationary processor.

12. A power converter according to claims 1 and 4, **characterized** in that the receiver/transmitter (14) rotating with the shaft, for receiving/transmitting digital data, and which is connected to the processor (12) rotating with the shaft, is arranged as an integral part of a processor rotating with the shaft.

13. A power converter according to claims 1 and 4, **characterized** in that the stationary receiver/transmitter (17) for receiving/transmitting digital data, and which is connected to the stationary processor (13), is arranged as an integral part of a stationary processor.

14. A method for power conversion with the aid of a power converter (1, 2) comprising at least one rotating electric machine with a converter (4) rotating with the shaft, which method is **characterized** in that on the rotating

electric machine, and rotating with the shaft, there is a digital processor (12), and that there is a stationary digital processor (13), and that the communication between the processor rotating with the shaft and the stationary processor is performed by means of a wireless communication link (14, 15, 16, 17).

AMENDED CLAIMS
[received by the International Bureau on 19 September 2000 (19.09.00);
original claims 1-14 replaced by new claims 1-5 (3 pages)]

1. A power converter with a rotating electric main machine (1), which main machine has a rotor shaft (3), a rotor winding (7), and an alternating current stator winding (5) for coupling to a power network, a converter (4) rotating with the shaft, a first control equipment (12) rotating with the shaft, an alternating voltage source (2), a stationary second control equipment (13), and a digital wireless communication link (14, 15, 16, 17) between the first and the second control equipment, **characterized** in that the rotor winding of the main machine is an alternating current winding, that the alternating voltage source is a regulating machine (2) with a rotor rotating with the shaft of the main machine and with a rotor winding (8) that is a multiphase alternating current winding, that the converter is an ac-to-ac converter (4) coupled between the rotor windings of the regulating machine and of the main machine, and that the first control equipment comprises a programmable first digital processor (12) programmed with software to, via control of amplitude and frequency of the voltage supplied to the rotor winding of the main machine, control the power converter in dependence on reference values supplied from the second control equipment via the communication link.

2. A power converter as claimed in claim 1, **characterized** in that said first digital processor is programmed with software to control the converter to
- during normal operation operate as an ac-to-ac converter,
- during start-up operate as one of an alternating current multiphase coupler, an alternating current phase-angle/voltage controller, and an alternating current short-circuit coupler, and

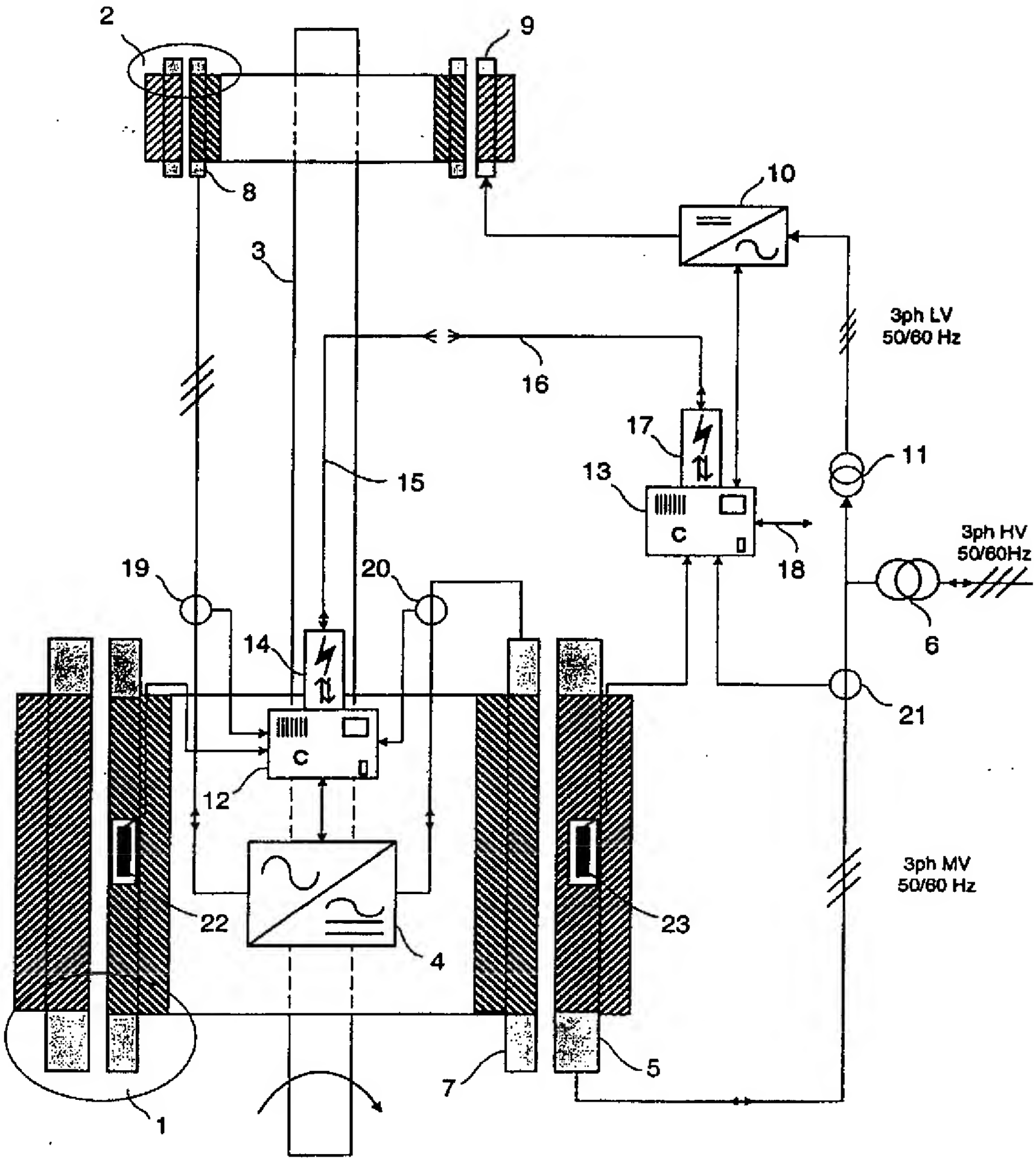
- during controlled breaking and stopping operate as one of an alternating current multiphase coupler, an alternating current phase-angle/voltage controller, and an alternating current short-circuit coupler.

3. A power converter as claimed in any of the preceding claims, **characterized** in that said first digital processor is programmed with software to temporarily and autonomously control the power converter in case of repeated and severe disturbances in the digital wireless communication.

4. A power converter as claimed in any of the preceding claims, **characterized** in that said second control equipment comprises a programmable second digital processor (13) programmed with software to generate said reference values in dependence on measured values of quantities associated with the power converter, and to communicate with super-ordinated control systems.

5. A method for power conversion with a power converter with a rotating electric main machine (1), which main machine has a rotor shaft (3), a rotor winding (7), and an alternating current stator winding (5) for coupling to a power network, a converter (4) rotating with the shaft, a first control equipment (12) rotating with the shaft, an alternating voltage source (2), a stationary second control equipment (13), and a digital wireless communication link (14, 15, 16, 17) between the first and the second control equipment, wherein the rotor winding of the main machine is an alternating current winding, the alternating voltage source is a regulating machine (2) with a rotor rotating with the shaft of the main machine and with a rotor winding (8) that is a multiphase alternating current winding, the converter is an ac-to-ac converter (4) coupled between the rotor windings of the

regulating machine and of the main machine, and the first control equipment comprises a programmable first digital processor (12), **characterized** in that reference values for the power conversion are supplied to the first control equipment from the second control equipment via the communication link, and that the first digital processor is programmed with software to control the power converter by controlling the amplitude and frequency of the voltage supplied to the rotor winding of the main machine in dependence on said reference values.


2
9
10
8
3
16
17
15
13
C
18
11
3ph LV
50/60 Hz
19
20
14
3ph HV
50/60Hz
6
21
C
12
22
4
23
3ph MV
50/60 Hz
7
5
1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/00707

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H02H 7/06, H02P 9/10, H02K 19/00, H04B 5/00, H04L 12/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H02H, H02K, H02P, H04B, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3671850 A (WALTER E. MEHRNET ET AL), 20 June 1972 (20.06.72), column 1, line 54 - line 60; column 2, line 55 - line 75; column 3, line 1 - line 17, abstract, see the figures --	1-14
A	US 4723106 A (IRVING A. GIBBS ET AL), 2 February 1988 (02.02.88), column 2, line 3 - line 19; column 3, line 57 - line 68; column 4, line 1 - line 2, abstract --	3
A	WO 9627939 A1 (SIEMENS AKTIENGESELLSCHAFT), 12 Sept 1996 (12.09.96), page 14, line 26 - line 30, figure 1, abstract --	3

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 July 2000	26 -07- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Hans Bagge af Berga/mj Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/00707

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Elkrafthandboken, Elkraftsystem 1 chapter 11, page 305-324 ISBN 91-00064-3 -- --------	3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SE 00/00707

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3671850 A	20/06/72	NONE	
US 4723106 A	02/02/88	CN 1007394 B	28/03/90
		DE 3750146 D,T	10/11/94
		EP 0258760 A,B	09/03/88
		JP 63059799 A	15/03/88
WO 9627939 A1	12/09/96	DE 19507760 A	12/09/96